APPENDIX D

Runoff Calculations

Introduction

The San Francisco Electric Reliability Project (at the MUNI Site) is a simple cycle, natural gas fired, combustion turbine generator (CTG) power plant using three GE LM6000PC Spring CTG units. The MUNI site is located on a brownfield site on the eastern project line of the MUNI Metro East Maintenance and Operation Facility (under construction).

Grading and Drainage

The plant site is located in an area that is currently unoccupied and generally of flat topography, sloping towards the San Francisco Bay. It is not anticipated that off-site areas contribute significantly to runoff at the site.

The general site grading will establish a working surface for construction and plant operating areas, provide positive drainage from buildings and structures, and provide adequate ground coverage for subsurface utilities.

Onsite drainage will be accomplished through gravity flow. The surface grading will direct stormwater runoff to the proposed vegetated swale collection system via overland flow at a minimum of 0.5%.

Stormwater Runoff Regulation

Stormwater discharges from the site are regulated by the RWQCB. Most of the stormwater runoff generated within the City and County of San Francisco is collected in a combined sewer system and conveyed to the Southeast and Oceanside water pollution control plants. However, a substantial portion of the Port of San Francisco, including the project site, is not serviced by the combined system. Stormwater discharges from these areas, not serviced by the combined system, are subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program.

The Port's SWMP includes guidance to be used when considering new development within the Port. The requirement most relevant to evaluation of the feasibility of the proposed project site design concerns sizing and design of the pollutant treatment system. The following is an excerpt from the SWMP (as taken from the California Stormwater BMP Handbook):

> ***Numeric Sizing Criteria for Pollutant Removal Treatment Systems.*** *The provisions provide specific design criteria for treatment BMPs. The project area threshold for the design criteria is defined as 5,000 square feet of new or redevelopment. The permits require treatment BMPs to be sized using… flow hydraulic design criteria for the design of treatment BMPs whose primary mode of action depends of flow capacity, such as* ***swales****, sand filters or wetlands. These types of BMPs are required to be sized to treat: 10% of*

the 50-year peak flow rate; or the flow of runoff produced by a rain event equal to at least two times the 85th percentile hourly rainfall intensity for the applicable area, or the runoff resulting from a rain event equal to at least 0.2 inches per hour.

As specified, the intensity of rainfall that requires treatment is 0.2 inches per hour. It is estimated that treating this rate of rainfall with flow-based BMPs would result in treatment of, on average, 85 percent of the total average annual rainfall.

The following steps describe the approach for application of the flow-based BMP design criteria:

1. Identify the "BMP Drainage Area" that drains to the proposed BMP. This includes all areas that will contribute runoff to the proposed BMP.

2. Determine rainfall intensity criteria to apply and the corresponding design rainfall intensity.

    a. *Uniform Intensity Approach:* The "Design Rainfall Intensity" is the intensity specified in the criteria – 0.2 inches/hour.

3. Calculate the composite runoff coefficient "C" for the "BMP Drainage Area" identified in Step 1.

4. Apply the Rational Formula to calculate the "BMP Design Flow"

    a. *Uniform Intensity Approach:* Using the "BMP Drainage Area" from Step 1, the "Design Rainfall Intensity" from Step 2a, and "C" from Step 3, apply the Rational Formula. The result is the "BMP Design Flow."

This method used the Rational Method equation:

$$Q = CIA$$

Where:

Q is the design flow in cubic feet per second (cfs),
C is the drainage area runoff coefficient,
I is the design intensity (in/hr), and
A is the drainage area for the BMP (acres)

Step 1. Determine the <u>drainage area</u> for the BMP, A = <u>5.23 </u> acres

Step 2. Determine the <u>runoff coefficient</u>, C = <u> 0.90</u>

Step 3. Use a design intensity of **0.2 in/hr** for "I" in the Q = CIA equation

I = 0.2 in/hour

Step 4. Determine the design flow (Q) using Q = CIA

Q = C*I*A

Q = (Step 2) * (0.2 in/hr) * (Step 1)

Q = 0.94 cfs

Design Flow, Q = 0.94 cfs

Therefore, the vegetated swale must be sized to accommodate the design flow.

Vegetated Swale Treatment Method

As detailed in the California Stormwater BMP Handbook, vegetated swales are open, shallow channels with vegetation covering the sides slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils.

Design and Sizing Guidelines

- Flow rate based design sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity
- Swale should be designed so that the water level does not exceed 2/3 the height of the grass or 4 inches, whichever is less, at the design treatment rate.
- Longitudinal slopes should not exceed 2.5%.
- The side slopes should be no steeper than 3:1 (H:V).
- Trapezoidal channels are normally recommended.
- The width of the swale should be determined using Manning's Equation using a value of 0.25 for Manning's n.
- The swale should have a length that provides a minimum hydraulic residence time of at least 10 minutes.

Attached please find a spreadsheet detailing the swale design calculations.

Assumptions

- Design grass height of 6 inches and a water quality flow depth of 4 inches, California Stormwater BMP Handbook, New Development and Redevelopme
- Manning's roughness coefficient of 0.25, California Stormwater BMP Handbook, New Development and Redevelopment
- Swale side slopes maximum steepness of 3:1, California Stormwater BMP Handbook, New Development and Redevelopment
- Minimum hydraulic residence time of 10 minutes, California Stormwater BMP Handbook, New Development and Redevelopment

Flow Rate Calculation

Area ID	Area	C	A*C	
Plant Area (approx.)	227,960	0.9	4.71	
		Sum A*C	4.7	
	Area volumetric flow rate		0.94	cfs
	Upstream flow		0.00	cfs
	Total volumetric flow rate		0.94	cfs

Swale Design Calculations

Variables				
		Design Flow Rate	0.94	cfs
i	0.2			
n	0.25	Flow Depth	0.33	ft
R	0.35	Manning's Equation	1.20	cfs
S	0.5%			
A	5.8	Flow Velocity	0.16	ft/s
Z	4	Min. Length	98	ft
b	16			
DT	10			

C = runoff coefficient
i = rainfall intensity (inches per hour)
n = Manning's Roughness Coefficient
R = hydraulic radius
S = hydraulic slope of swale
A = swale cross-section area (square feet)
z = swale side slope ratio (x:1)
b = width of bottom of swale (feet)
Q = volumetric flow rate (cubic feet per second)
DT = detention time (minutes)
cfs = cubic feet per second
ft/s = feet per second

A = (b+z*y)*y
R = A/(b+2*(y^2+y^2*z^2)^0.5
Q= 1.49/n(A*R^2/3*S^1/2)

Vegetated Swale 100-year, 1-hour Storm Capacity Calculations

Calculations have been requested to illustrate that the vegetated swale has been sized to not only treat the water quality storm but to carry the post-construction 100-year peak runoff from the SFERP site. The following steps were taken to do so:

1. Identify the "Drainage Area" that drains to the proposed swale. This includes all areas that will contribute runoff.

2. Determine rainfall intensity criteria to apply and the corresponding design rainfall intensity.

    a. The rainfall intensity duration used for this calculation are based on the rainfall information collected by the Department of Water Resources rain gauge at the San Francisco International Airport. An empirical equation has been developed based on rainfall data collected over an almost fifty-year period. The equation is:

    $$\mathbf{I = A * D^B}$$

    Where:

    A is a constant based on the rainfall frequency
    For 10 year frequency A = 0.88
    For 25 year frequency A = 1.04
    For 100 year frequency A = 1.28
    D is the rainfall duration in hours
    B is the site specific constant (-0.484)
    I is the intensity for the designed rainfall frequency/duration (in/hr)

    A table of this IDF curve is attached, which indicates that for a 100-year frequency and 15-minute duration (assuming that the peak producing period of the storm has a duration equal to an estimated time of concentration of fifteen minutes) the Intensity "I" = 2.504.

3. Calculate the composite runoff coefficient "C" for the "Drainage Area" identified in Step 1.

4. Apply the Rational Formula to calculate the Design Flow

    a. Using the "Drainage Area" from Step 1, the "Rainfall Intensity" from Step 2a, and "C" from Step 3, apply the Rational Formula. The result is the "Design Flow."

This method used the Rational Method equation:

$$Q = CIA$$

Where:

Q is the design flow in cubic feet per second (cfs),
C is the drainage area runoff coefficient,
I is the design intensity (in/hr), and
A is the drainage area to the swale (acres)

Step 1. Determine the drainage area for the BMP, A = 5.23 acres

Step 2. Determine the runoff coefficient, C = 0.99

The Manning's coefficient has been increased to 0.99 to reflect total imperviousness at the site.

Step 3. Use a design intensity of **2.50 in/hr** for "I" in the Q = CIA equation

I = 2.50 in/hour

Step 4. Determine the design flow (Q) using Q = CIA

Q = C*I*A

Q = (Step 2) * (2.50 in/hr) * (Step 1)

Q = 12.97 cfs

Design Flow, Q = 12.97 cfs

Therefore, the vegetated swale must be sized to not only treat the water quality storm but to carry this post-construction 100-year peak runoff.

Attached please find a spreadsheet detailing that the swale will carry in excess of the 100-year peak runoff at a depth of 1.30 feet. This in excess of the estimated swale depth of 1.00 feet. Therefore, the swale must be deeper to carry this increased rate-of-runoff

Stormwater Drainage Design
San Francisco Electric Reliability Project
MUNI Site

Flow Rate Calculation				
	Area	C	A*C	
Power Plant, Swale and 25th Street.	227,819 sf = 5.23 Ac.	0.99	5.18	
		Sum A*C	5.18	
	Area volumetric flow rate		12.96 cfs	*(A*C*rainfall intensity "i")*
	Upstream flow		0.00 cfs	
	Total volumetric flow rate		12.96 cfs	

Swale Design Calculations			
Variables		Design Flow Rate	12.96 cfs
i	2.50		
n	0.25	Flow Depth	**1.30** ft
R	1.39	Manning's Equation	**13.58** cfs
S	0.5%		
A	25.9	Flow Velocity	0.50 ft/s
Z	3	Min. Length	301 ft
b	16		
DT	10		

C = runoff coefficient
i = rainfall intensity (inches per hour)
n = Manning's Roughness Coefficient
R = hydraulic radius
S = hydraulic slope of swale
A = swale cross-section area (square feet)
z = swale side slope ratio (x:1)
b = width of bottom of swale (feet)
Q = volumetric flow rate (cubic feet per second)
DT = detention time (minutes)
cfs = cubic feet per second
ft/s = feet per second

A = (b+z*y)*y
R = A/(b+2*(y^2+y^2*z^2)^0.5
Q= 1.49/n(A*R^2/3*S^1/2)

INTENSITY DURATION FREQUENCY
California Department of Water Resources IDF Data Base
SF Airport Station

DURATION	INTENSITY (IN / HR)				INTENSITY (MM / HR)			
	10YR	25YR	50YR	100YR	10YR	25YR	50YR	100YR
0	0	0	0	0	0	0	0	0
5	2.930	3.462	3.862	4.261	74.412	87.941	98.088	108.235
6	2.682	3.170	3.536	3.901	68.127	80.513	89.803	99.093
7	2.489	2.942	3.281	3.621	63.229	74.725	83.347	91.969
8	2.334	2.758	3.076	3.394	59.272	70.048	78.131	86.213
9	2.204	2.605	2.906	3.206	55.987	66.167	73.801	81.436
10	2.095	2.475	2.761	3.047	53.204	62.877	70.132	77.387
11	2.000	2.364	2.637	2.909	50.805	60.042	66.970	73.898
12	1.918	2.266	2.528	2.789	48.710	57.566	64.209	70.851
13	1.845	2.180	2.432	2.683	46.859	55.379	61.769	68.159
14	1.780	2.103	2.346	2.589	45.208	53.428	59.592	65.757
15	1.721	2.034	2.269	2.504	43.723	51.673	57.635	63.598
16	1.668	1.972	2.199	2.427	42.379	50.084	55.863	61.642
17	1.620	1.915	2.136	2.357	41.153	48.636	54.247	59.859
18	1.576	1.863	2.077	2.292	40.030	47.309	52.767	58.226
19	1.535	1.814	2.024	2.233	38.996	46.087	51.404	56.722
20	1.498	1.770	1.974	2.178	38.040	44.957	50.144	55.331
21	1.463	1.729	1.928	2.128	37.152	43.907	48.974	54.040
22	1.430	1.690	1.885	2.080	36.325	42.930	47.883	52.837
23	1.400	1.654	1.845	2.036	35.552	42.016	46.864	51.712
24	1.371	1.620	1.807	1.994	34.827	41.159	45.909	50.658
25	1.344	1.589	1.772	1.955	34.146	40.354	45.011	49.667
26	1.319	1.559	1.739	1.919	33.504	39.595	44.164	48.733
27	1.295	1.531	1.707	1.884	32.897	38.879	43.365	47.851
28	1.273	1.504	1.677	1.851	32.323	38.200	42.608	47.016
29	1.251	1.479	1.649	1.820	31.779	37.557	41.891	46.224
30	1.231	1.455	1.622	1.790	31.262	36.946	41.209	45.472
31	1.211	1.432	1.597	1.762	30.770	36.364	40.560	44.756
32	1.193	1.410	1.572	1.735	30.300	35.810	39.941	44.073
33	1.175	1.389	1.549	1.710	29.853	35.280	39.351	43.422
34	1.158	1.369	1.527	1.685	29.424	34.774	38.787	42.799
35	1.142	1.350	1.506	1.662	29.014	34.290	38.246	42.203
36	1.127	1.332	1.485	1.639	28.621	33.825	37.728	41.631
37	1.112	1.314	1.466	1.617	28.244	33.380	37.231	41.083
38	1.098	1.297	1.447	1.597	27.882	32.952	36.754	40.556
39	1.084	1.281	1.429	1.577	27.534	32.540	36.295	40.049
40	1.071	1.265	1.412	1.558	27.198	32.144	35.853	39.561
41	1.058	1.250	1.395	1.539	26.875	31.762	35.427	39.091
42	1.046	1.236	1.379	1.521	26.564	31.393	35.016	38.638
43	1.034	1.222	1.363	1.504	26.263	31.038	34.619	38.201
44	1.023	1.208	1.348	1.487	25.972	30.695	34.236	37.778
45	1.011	1.195	1.333	1.471	25.691	30.362	33.866	37.369
46	1.001	1.183	1.319	1.456	25.419	30.041	33.508	36.974
47	0.990	1.170	1.306	1.441	25.156	29.730	33.161	36.591
48	0.980	1.159	1.292	1.426	24.901	29.429	32.824	36.220
49	0.971	1.147	1.279	1.412	24.654	29.136	32.498	35.860
50	0.961	1.136	1.267	1.398	24.414	28.853	32.182	35.511
51	0.952	1.125	1.255	1.385	24.181	28.578	31.875	35.173
52	0.943	1.115	1.243	1.372	23.955	28.310	31.577	34.844
53	0.934	1.104	1.232	1.359	23.735	28.051	31.287	34.524
54	0.926	1.094	1.221	1.347	23.521	27.798	31.005	34.213
55	0.918	1.085	1.210	1.335	23.313	27.552	30.731	33.910
56	0.910	1.075	1.199	1.323	23.111	27.313	30.464	33.616